Journal of Environmental Management 236 (2019) 490–498

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

An analysis of conservation practice adoption studies in agricultural human-natural systems

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ARTICLE INFO

Keywords:
Farmer ability and willingness
Agri-environmental governance
Institutional dimensions
Coupled human-natural systems

ABSTRACT

Farmers' conservation decisions are central to addressing regional environmental challenges, such as biodiversity loss, water quality impairment, or climate change. However, three decades of substantial investment in agri-environmental programs has not yielded widespread adoption or improved environmental outcomes. It remains difficult to explain why farmers adopt despite an extensive body of research on the topic. One possible reason for this is that researchers are limiting the types of metrics they are analyzing to explain farmer decisions. We systematically and critically evaluated the social science adoption literature to address three important gaps: (1) How are adoption studies measuring adoption effectiveness? (2) How do studies integrate individual farmer perspectives into broader institutional (i.e., social and governance) contexts? (3) What are the most prevalent metrics that adoption research uses to characterize the human-natural system? We coded 174 studies and found that only 10% connect adoption decisions to conservation outcomes or undertake longitudinal research, while the dominant approach in adoption research excludes the institutional contexts in which farmers are situated. The most prevalent metrics focus on farmer demographics, financial and technical capacity to adopt, and economic motivations. The lack of attention to both conservation outcomes and longitudinal studies limits researchers' ability to analyze the effectiveness of CP adoption. To advance our understanding of adoption, we recommend that future research measure conservation outcomes and track how knowledge about adoption effectiveness feeds back into farmer perceptions and social norms towards adoption. Research should also consistently measure how agri-environmental programs mediate the social acceptability of adoption. Lastly, institutional metrics that can be widely incorporated into coupled human-natural systems research will advance synthesis efforts to better explain why farmers adoption conservation practices.

1. Introduction

Despite an extensive body of research, it remains difficult to predict why farmers adopt (or do not adopt) conservation practices (CPs) (Knowler and Bradshaw, 2007; Prokopy et al., 2008; Baumgart-Getz et al., 2012; Burton, 2014). Whether or not farmers adopt CPs is critical to overcoming regional and global environmental challenges, such as biodiversity loss, climate change, and water quality degradation because farmers and herders in combination manage nearly 40% of terrestrial biomes globally (Foley et al., 2005). Three decades of substantial investment in voluntary on-farm CPs from governmental and non-government programs has not been sufficient to dramatically improve water quality or biodiversity (Ribaudo, 2015; Siebert et al., 2006). Different studies have shown that about 20% of farms participate in agri-environmental programs in Europe (Siebert et al., 2006), while participation rates on specific measures can range from 4 to 33% (Dedeurwaerdere et al., 2015). In the United States, adoption of soil conservation measures to improve water quality, such as strip or minimum tillage, vary widely by region and crop type, ranging from 30 to 45% (Wade et al., 2015). While there have been important reductions in soil erosion, farms continue to have unsustainable soil losses despite both subsidy and compliance programs (Arbuckle, 2013). These challenges indicate that there is much still to learn about *why* farmers adopt CPs and whether CP adoption is *effective* in generating the environmental outcomes of interest (Uthes and Matzdorf, 2013; Reimer et al., 2014).

In this study we systematically assess and critically evaluate the CP adoption literature in order to improve research on why farmers adopt

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https://doi.org/10.1016/j.jenvman.2019.02.009
Received 31 August 2018; Received in revised form 10 December 2018; Accepted 2 February 2019
Available online 13 February 2019
0301-4797/

Table 1
Adoption keywords for literature search.

Best management practice	Agri-environment	Pro-environment
Conservation practice	Conservation measure	Environmental behavior
Payment for ecosystem service	Payment for environmental service	Conservation subsidy

CPs. This body of literature has many case studies but few synthesis efforts. Prior literature reviews have highlighted critical gaps and challenges in adoption research, especially shortcomings around methodologies (Lockeretz, 1990; Burton, 2014), inconsistent directions and statistical significance of correlations for theoretically important variables (Knowler and Bradshaw, 2007; Prokopy et al., 2008; Baumgart-Getz et al., 2012), and the need for longitudinal research and greater emphasis on biophysical outcomes (Uthes and Matzdorf, 2013; Reimer et al., 2014). We are particularly concerned with three aspects of the social science literature that we expect contribute to the inconsistencies and shortcomings of existing adoption research identified by existing syntheses (Prokopy et al., 2008; Reimer et al., 2014).

First, social science adoption research has not connected conservation outcomes to adoption to gauge CP effectiveness (Uthes and Matzdorf, 2013). Studies have rarely examined whether farmers maintain CPs over time or measured the extent or rigor of adopted practices (Reimer et al., 2014). This is particularly problematic since the lack of outcome measures means it is difficult to connect CPs to specific biophysical dimensions of farms and their surrounding regions. Moreover, the lack of longitudinal studies makes it difficult to track adoption over time in connection to outcomes (Reimer et al., 2014). Natural science studies have documented long time lags to detect noticeable changes for water quality improvement tied to adoption (Melland et al., 2018). Whether and how outcome data might feed back into farmer decision-making offers an additional dynamic that would benefit from coupled human-natural systems research.

Second, while the literature makes clear that both individual farmer perspectives (i.e., attitudes, values, etc.) and institutional factors (i.e., rules and norms) matter for CP adoption, they have rarely been considered jointly. Past literature reviews indicate that adoption research has tended to examine farmer demographics, farm characteristics, and economic incentives, while overlooking important socio-cultural variables that could strongly encourage or discourage adoption (Burton, 2004; Siebert et al., 2006). Emerging research also indicates that governance arrangements alongside financial factors and personal motivations are crucial to the widespread uptake of CPs (Burton and Paragahawewa, 2011; Leventon et al., 2017; Toderi et al., 2017). Research will not be able to predict the likelihood of adoption without situating farmer motivations in specific socio-cultural and governance contexts. Similarly, if the effectiveness of adopted practices is also missing, researchers cannot gauge the impact that such knowledge will have on adoption or non-adoption over time.

Third, the diversity in the theoretical framings and approaches of prior literature makes it difficult to synthesize across cases and identify existing areas of agreement and remaining gaps. It is unclear just how many different metrics researchers are analyzing and what opportunities or challenges this poses for future synthesis. While there is no consensus framework on adoption, many studies refer to farmer ability and willingness as key aspects (Siebert et al., 2006). Other research relies on the Theory of Planned Behavior, which focuses on farmer self-perceptions of ability, attitudes, and social norms (Mills et al., 2017), or focus more specifically on farm economics in driving decision-making (La Notte et al., 2015). Quantifying the metrics that researchers study will show what aspects have received the most or least attention to improve future research on adoption.

Our systematic analysis of the social science adoption literature quantifies the extent to which conservation outcomes are connected to adoption, the frequency of studies integrating individual and institutional factors, and which metrics are most prevalent within the diversity of existing approaches. To those ends, we address three related questions: (1) What adoption metrics are used to measure conservation outcomes and gauge adoption effectiveness? (2) To what extent are studies integrating individual farmer perspectives into the broader institutional contexts in which farmers are situated? (3) What are the most prevalent metrics that adoption research uses to characterize the human-natural system? We do not attempt to analyze whether metrics are correlated with adoption, as several literature reviews have already addressed this question in detail (e.g., Prokopy et al., 2008; Baumgart-Getz et al., 2012). Instead, our approach focuses on understanding these three key aspects to clarify where a coupled human-natural systems framework can build on existing knowledge and facilitate greater synthesis.

2. Search criteria and methods

In order to analyze the adoption literatures, we conducted a series of targeted searches using the Clarivate Analytics Web of Science search engine, following Ward (2016). We first developed a series of keyword search terms based on familiarity with the literature for the purposes of compiling a wide range of ways that researchers refer to on-farm CPs (hereafter referred to as *adoption keywords*). We used this variety of adoption keywords to capture broad geographic coverage and not limit the results to high input, high output, and highly subsidized approaches in Europe and North America. We then used an iterative process of multiple trial searches to weed out terms that had very small numbers of returned results to settle on a final list of eight adoption keywords (Table 1). Second, we combined this string of adoption keywords with 16 search terms to capture different emphases among adoption research approaches (hereafter *research keywords*). We purposively choose these terms based on our familiarity with the literature to equally represent individual farmer perspectives and institutional dimensions of farmer interactions, with eight in each category perspectives (Table 2). In combination, these two steps provided us with a tailored set of results relevant to our focus on how researchers are characterizing the coupled human-natural system.

We then conducted 16 research keyword searches using the Web of Science search engine on 2 January 2018. We limited searches to English-language, peer-reviewed journal articles published from 1900 to 2017. Each search combined the entire string of adoption keywords to ensure adoption was present as a theme in each study (Table 1) with one of the research keywords to differentiate between research approaches that were used (Table 2). As an example, the search code for the research keyword "attitude" was:

TS = ((farmer attitude) and ("best management practice" or agri-

Table 2
Research keywords for literature search.

Individually Focused Keywords	*Institutionally Focused Keywords*
Adoption	Collaboration
Attitude	Collective Action
Decision-making	Common-Pool Resources
Identity	Cooperation
Knowledge	Diffusion of Innovations
Motivation	Governance
Perception	Participation
Values	Watershed Partnerships

environment or pro-environment* or (conservation practice) or (conservation measure) or "environmental behavior" or (payment for ecosystem service) or (payment for environmental service) or (conservation subsid*)))

The full search string for each search is included in the supplementary materials.

2.1. Sampling and coding approach

Given the large number of results, we purposively sampled by sorting each of the 16 searches by the Web of Science's "relevance" algorithm and then coded the top 20 results in each search (following Ward, 2016 and Gerlak et al., 2017). While non-random, the value of introducing this bias is to prioritize studies that are important to our understanding of adoption research. We excluded five review papers and one unobtainable article from the sample set, including instead the next results sorted by relevance in these instances. To analyze the different metrics used in the sampled articles, we employed a combination of descriptive, inductive, and iterative coding approaches. To code for the different ways individual studies analyzed adoption, we developed an initial set of specific criteria to measure the frequency of different metrics (hereafter referred to as *codes* or *metrics*; Saldaña, 2016). This started with metrics on adoption effectiveness (i.e., conservation outcomes tied to adoption), binary measures of adoption or non-adoption, intention to adopt, and explanations of non-adoption. Over time, we expanded this list to include intensity of adoption measures (e.g., frequency or geographic extent), participation in conservation program, proxy measure of likely adoption, and spatial analysis. Adoption metrics do not necessary represent the dependent variable in all studies, which reflects the diversity of ways in which researchers are studying conservation practices.

Similarly, to examine whether studies focused primarily on individual farmer perspectives or addressed institutional dimensions shaping farmer interactions, we started with specific codes to create binary present or absent results for these criteria. There is substantial diversity across quantitative and qualitative methods and we felt this approach was necessary to be able to provide descriptive statistics on frequency. We coded for whether studies measured farmers' individual perspectives, such as attitudes, economic motivations, or risk perceptions through surveys, or examined institutional arrangements influencing farmer behavior, ranging from description of rules, farmer quotes about peer learning or pressure, examples of social norms affecting adoption or non-adoption, to other forms of interaction. To some extent this reflects the quantitative or qualitative approaches of sampled articles. Surveys effectively only measure individual perspectives on adoption since farmer interactions are rarely addressed, while qualitative approaches may use narrative analyses that examine people's interactions but do not report individual perspectives. We coded for this separately from other metrics to better gauge integration between farmer perspectives and institutional dimensions.

Finally, to assess which metrics are most frequently used to characterize human-natural systems, we employed an inductive approach to identify and code the range of metrics used to examine drivers of adoption. While farmer demographic characteristics, such as age or education were largely uniform, researchers characterized many other variables in diverse ways. For analytical purposes, we iteratively grouped together variables focused on similar concerns. Based on our inductive and iterative coding, we settled on 83 total metrics, excluding any codes that did not appear in at least five studies after being iteratively grouped together (supplementary materials). We also organized metrics into four conceptual areas to help visualize this distribution, and which reflects how other researchers have tended to characterize the human-natural system (Fig. 5). These include (1) farmer ability and (2) willingness to adopt CPs, (3) social influences, and (4) governance arrangements (e.g., Morris et al., 2000; Siebert et al., 2006; Prokopy et al., 2008; Mills et al., 2017). We followed prior research on where metrics fit into conceptual areas. For example, farmer age and gender/sex are theorized to influence farmers' willingness to adopt CPs (Burton, 2014). Only the lead author coded metrics. In the supplementary materials, definitions for each code and every coding decision for all 174 articles are included for full transparency of these decisions.

2.2. Limitations

There are several methodological limitations to our systematic and critical analysis of the adoption literature. First, we have intentionally cast a wide net and have not limited our sample to a certain set of well-defined CPs for a specific environmental outcome. Our analysis is therefore limited in correlating or commenting on specific relationships between individually coded metrics and adoption or conservation outcomes. Systematic coverage of these aspects at the farm level would be necessary for conducting the coupled human-natural system research in the future. Second, our analysis is limited to social science research, excluding an extensive natural science body of research. Future work must integrate both social and natural science research. Our contribution provides a needed intermediate step by identifying the challenges within social science research.

3. A diverse and growing literature

The 16 searches generated 2,044 unique peer-reviewed journal articles with substantial ranges across research keywords. Many articles were cross-listed on multiple searches, including a half-dozen papers appearing on more than six searches. The search with the most results was "adoption" with 843, while "diffusion of innovations" had the fewest with 36 results (Fig. 1). The individual searches demonstrate that some research keywords are far more prevalent than others. Some individually and institutionally focused research keywords have hundreds of studies each, suggesting there is an extensive base of knowledge on adoption in some sub-sets of the literature. While there are many cross-listed results, there are a few instances where the lack of overlap is surprising. For example, it is unsurprising that adoption overlaps relatively little with collaboration (22 studies), collective action (14 studies), and cooperation (7 studies), as they focus on different units of decision-making (individual vs. group). But the latter three terms also overlap infrequently with common-pool resources, which is unexpected given the importance of collective action in governing common-pool resources, and illuminates the high level of fragmentation of the adoption literature (Table 3).

A timeline of publication dates shows that the adoption literature begins in the late 1980s. Most of the literature has emerged over the past 10 years, with more than 50% of the results published from 2012 to 2017 (Fig. 2). This is consistent with the timeline of agri-environmental efforts expanding beyond soil loss (which dates back to the early 20th century) that began largely in the 1980s (Burton and Paragahawewa, 2011; Ribaudo, 2015; Runhaar et al., 2017).

4. Analysis of adoption research: challenges for integrating conservation outcomes and institutional contexts

4.1. Only 10% of studies examine whether CPs generate environmental improvements

Our findings show that only 10% of studies (18 of the 174 we coded) attempted to resolve biophysical outcomes tied to adoption decisions (Fig. 3). The outcomes measured included soil health, sedimentation, and effluent loads (11 studies), wildlife, crop, and habitat biodiversity (5 studies), and ecosystem services and carbon footprints (2 studies). The vast majority of studies focused on different metrics of adoption decisions (Fig. 3). The most common adoption metric was a binary measure of *adopted* or *not adopted* (53 studies), which is similar to findings of other reviews (Uthes and Matzdorf, 2013). This was

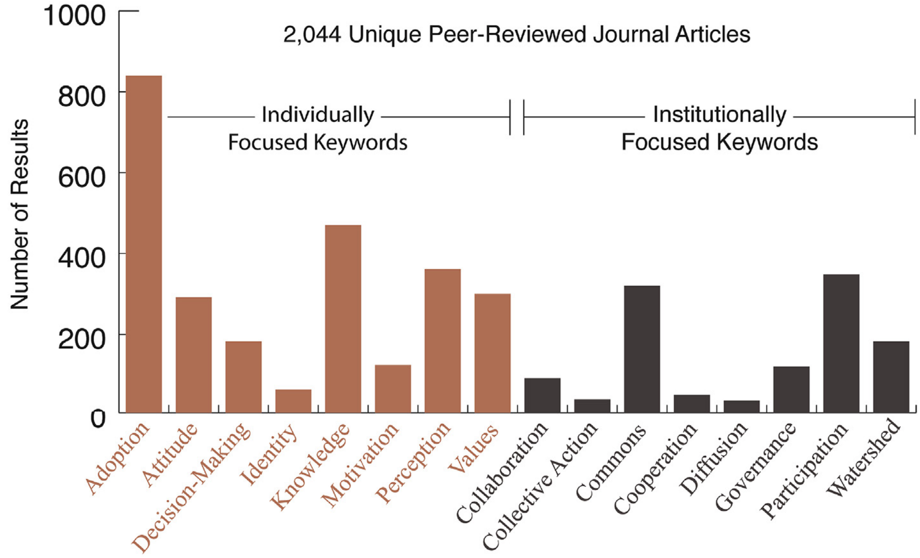


Fig. 1. Caption: Search results by research keywords yielded 2,044 unique peer-reviewed journal articles and revealed popularity and scarcity of certain keywords in the literature.

followed by *intention to adopt* (48 studies) and *participation in an agri-environmental program* (36 studies). Typically, *adopted or not adopted* and *intention to adopt* metrics were survey-based results on one or more practices specified by the authors, while *participation* metrics were often mentioned within case studies, often without examining whether specific CPs tied to program participation had been adopted. At the same time, researchers appear to be expanding the set of adoption metrics to document or quantify a wider range of aspects shaping adoption and non-adoption. Twenty-two studies gauged some degree of *adoption intensity*, such as ordinal measures to represent adoption amounts (Vignola et al., 2010) or acreage proportions (Groth and Curtis, 2017), while 14 studies incorporated *spatial analysis* within a region or farm, such as spatial clustering of farms participating in agri-environment programs (Van der Horst, 2011). The remaining 29 studies took more tangential approach, using a *proxy measure* to indicate whether a farmer would be a likely adopter, such as perceptions of self-efficacy (McNairn and Mitchell, 1992). Fifty-two studies captured more than one metric, while overall studies averaged 1.4 adoption metrics.

Alongside the absence of adoption effectiveness, few studies undertook longitudinal approaches. Only 18 studies used multiple time periods, while another 16 studies addressed stages of decision-making to incorporate time into their analysis. The advantage of incorporating temporal aspects into analysis is that it helps to show different pathways and feedbacks into decision-making, which are crucial to deeper understanding of what economic, socio-cultural, and policy tools are likely to make adoption effective. In particular, it helps to show how farmers respond to agri-environmental subsidies, market pressures, and knowledge shared by governmental conservation advisors (Wynne-Jones, 2013; Boardman et al., 2017). It also directs attention to the ways in which farmers negotiate arguments and values with their peers, especially based on feedbacks concerning environmental outcomes, to challenge existing social norms or draw on socially acceptable rationales in advancing new cases for conservation practices (McGuire et al., 2013; Riley, 2016). In combination, the lack of attention to both conservation outcomes and longitudinal studies in the literature limits researchers' ability to analyze the effectiveness of CP adoption in connections to biophysical contexts and farm production approaches and also how those outcomes in turn feed back into farmer perceptions and farming community discourses.

4.2. Adoption research seldom situates farmers in their institutional contexts

Overall, current research has limited its focus to decision-making within farm boundaries, as supported by two lines of evidence. First, the dominant research approach analyzed farmer perspectives in isolation from their institutional contexts (49%, 86 of 174 studies). More surprisingly, one-third of articles (57 studies) captured both individual perspectives and institutional contexts, indicating that researchers are at least considering this range of potential adoption drivers. Another 16% (27 studies) used institutional-only approaches, largely through narrative analysis, and four studies (2%) had neither, focusing instead on ecosystem services or economic calculations (Fig. 4). Methodology appears to shape whether individual or institutional aspects are examined. Three-fourths of studies that analyzed only individual farmer perspectives used quantitative approaches. For individual-institutional studies, qualitative approaches were the most common (46%), followed by quantitative approaches (32%), while mixed-methods were the least common (23%). Institutional-only studies had a similar methodological distribution to individual-institutional studies.

Second, the composition of coded metrics reveals that farmer demographics, financial and technical capacity to adopt, and economic motivations are more prevalent than metrics examining farmer interactions and governance arrangements. Metrics dealing with decision-making and constraints within individual farm boundaries constitute the eight most prevalent metrics overall. While some of the most prevalent metrics were measured similarly, such as *farm size, age, education, experience, and land tenure*, typically quantified through surveys, *need information or skills* and *financial capacity* represent more general categories capturing a range of ways that these are included, especially in qualitative studies. This could include authors qualitatively observing that knowledge of program specifics was low (Chen and Innes, 2013) or farmer respondents agreeing or disagreeing with a statement that subsidies are necessary as part of a Q method surveys (Zabala et al., 2017). Metrics more specific to institutional dimensions, generally aspects dealing with influences of social networks and governance arrangements, are less frequent overall. While the most common social and governance networks comprise a second tier of frequency, appearing in 20–30% of studies, the focus of the most common metrics documents the presence or absence of a connection or the type of governance arrangement, without necessarily addressing the ways in which these aspects influence behavior. For example, connections to *neighbors/peers* (45 studies), *a community of practice* (40 studies), or

Table 3

Caption: Table 3 shows how many studies are cross-listed by research keyword. It reveals the greater prevalence of individually focused keywords in the literature.

	Adoption	Attitude	Decisionmaking	Identity	Knowledge	Motivation	Perception	Values	Collaboration	Collective Action	Commons	Cooperation	Diffusion	Governance	Participation	Watershed
Adoption	**840**															
Attitude	122	**292**														
Decisionmaking	76	44	**183**													
Identity	17	18	6	**63**												
Knowledge	123	61	35	14	**470**											
Motivation	54	36	14	14	14	**124**										
Perception	162	92	44	13	97	34	**361**									
Values	48	46	26	16	39	25	41	**300**								
Collaboration	22	8	5	1	24	5	10	10	**91**							
Collective Action	14	5	2	3	9	7	6	2	2	**39**						
Commons	65	32	26	9	60	15	43	39	10	8	**320**					
Cooperation	7	7	3	0	6	3	7	3	10	6	10	**50**				
Diffusion	34	2	4	0	11	1	3	3	0	2	2	0	**36**			
Governance	30	9	10	5	37	8	19	11	15	4	23	10	0	**120**		
Participation	142	90	39	11	58	44	66	44	17	8	40	11	4	35	**348**	
Watershed	79	19	16	1	11	8	24	13	11	4	9	5	0	12	26	**183**

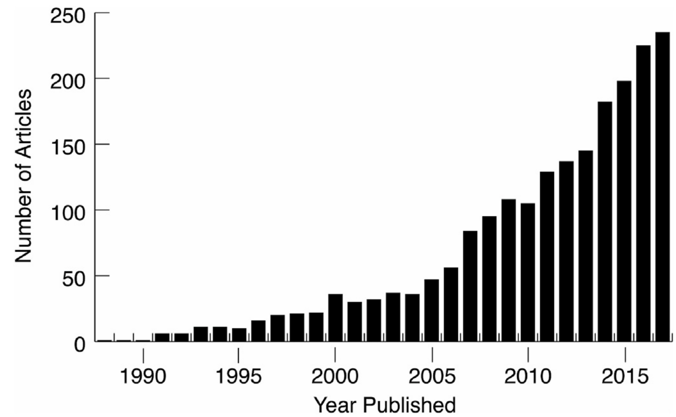


Fig. 2. Caption: The publication timeline of conservation adoption research shows a field growing exponentially and following the development of agri-environmental policies in the 1980s.

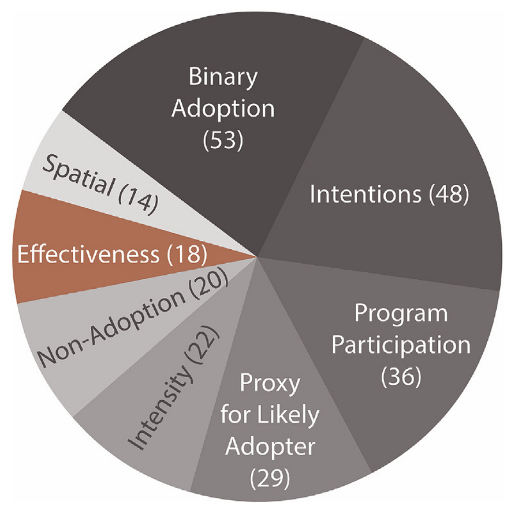


Fig. 3. Caption: Researchers use a range of metrics to measure adoption, but only 10% of studies connect conservation outcomes to adoption decisions to measure effectiveness.

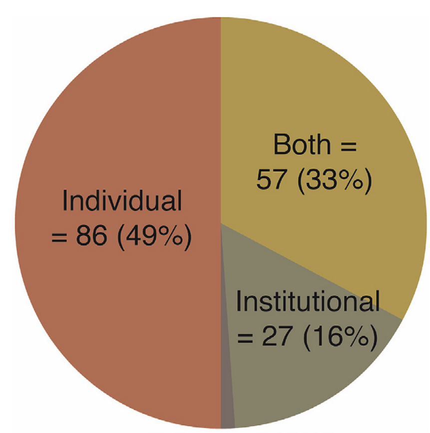


Fig. 4. Caption: The dominant research approaches does not situate farmer adoption decisions within their broader institutional contexts.

extension or conservation advisor (39 studies) occur one-fourth of studies overall, but nearly half of these are in individual-only studies where social interactions are not described since metrics are often measured through survey responses. For example, two other metrics had similar representation, but focused instead of farmer interactions: *cooperation/*

reciprocity (39 studies) and *social norms* (35 studies). These were also operationalized through a variety of measures, such as interview responses around needing or trying to cooperate within an agri-environmental program (Emery and Franks, 2012) or surveys asking about "group norms" (Dijk et al., 2016). Remaining social metrics decline to around 10%, such as *trust* (22 studies) or *public recognition* (18 studies).

Governance metrics are similar: the most common—*land tenure* (53 studies)*, government-led* (49 studies) or *collaborative initiatives* (42 studies), and *described program rules* (49 studies)—tend to describe the presence or absence of certain rules, rather than addressing underlying aspects of behavior. Less common metrics addressed more specific aspects of how governance affected participation were less common, such as *attitudes towards policy fairness* (30 studies)*, preference for flexibility/autonomy* (22 studies), and *administrative barriers* (15 studies). Measuring for the presence or absence of representative structural components, connections, and rules remain important and useful. Our point is not to criticize these existing approaches, but to show that other ways of more directly evaluating the causal effects of more precise social and governance aspects of institutional dimensions are essential. The value of these other measures is that they can help to illustrate key processes en route to a farmer's adoption decision.

4.3. Lack of a common framework inhibits the potential for synthesis

Based on inductively and iteratively coding variables, it is evident that there is no consensus on a common adoption framework. Only two metrics, *farm size* and *farmer age*, appeared in more than 50% of studies (Fig. 5). After those two variables, there is a long tail with only the next 10 metrics appearing in at least 25% of coded studies. We found that the most consistently used metrics focused on farmer ability, farm demographic information, or farm production characteristics. These included *farm production type* (70 studies), the *need for information or skills* (68 studies), *financial capacity* (62 studies)*, education* (59 studies), and *gender/sex* (57 studies). Consistent with the lack of studies measuring conservation outcomes, few studies addressed the biophysical variables of individual farms or of the study area. When included, the most common biophysical metrics were *soils* (27 studies), *precipitation* (22 studies), and *slopes* (18 studies), representing 10–15% of the 174 articles coded. The next most common variables addressed aspects of farmer economic motivations and environmental priorities, alongside the presence or absence of social network connections and rules governing agri-environmental policies, which were discussed in the previous section.

Overall, the substantial breadth of metrics being analyzed makes synthesis challenging. The clear advantage of this diversity is that it provides attention to how many factors can influence this complex system. One opportunity for using this diversity is to deploy metrics in combination. For example, 49 studies measured farmers' *environmental awareness* as a proxy to gauge whether this motivates farmers to adopt CPs. However, far less common were measures of whether farmers' perceived themselves as capable of adoption (*self-efficacy*, 21 studies) or if they considered the CPs to be environmentally effective (*effectiveness of CPs*, 17 studies). Farmers may possess high environmental awareness but believe a given CP is too complex or ineffective for their farm. In combination, these three variables were measured jointly only three times. Combinations of *need information or skills* (68 studies), *self-efficacy,* and *effectiveness of CP* yielded only one study. Deploying metrics in more strategic combination would help to rule out alternative explanations.

While researchers' characterizations of the human-natural system have achieved substantial breadth, depth across different aspects of the system is lacking (Fig. 5). Studies averaged 10.5 metrics overall. We found that ability metrics (3.9 per study) are used more than twice as frequently on average as social and governance metrics (1.8 per study each), and 30% more often than willingness metrics (3.0 per study). We also found that 80 studies had at least one metric in each category, but this drops to 34 studies that have two metrics in each, and only one study that had five metrics across each category (Fig. 6). The 11 studies with three or more metrics in each category provide rich characterizations of how farmer decisions are mediated by their institutional context (see Fleury et al., 2015 and Karali et al., 2014 as two examples). For example, Fleury et al. (2015) describe a process of negotiation between government officials and farmers to achieve consensus on agri-environmental biodiversity outcomes to be achieved and monitored, the types and fit of CPs with existing farm management needs, and positive social norms to help sustain CPs over time. The rich characterization illustrates the importance of analyzing multiple, interacting aspects of the human-natural system. While the breadth of metrics present may offer insights into what aspects need to be addressed in future syntheses, research must also pay more attention to providing a more robust characterization of the overall system.

5. Future research directions

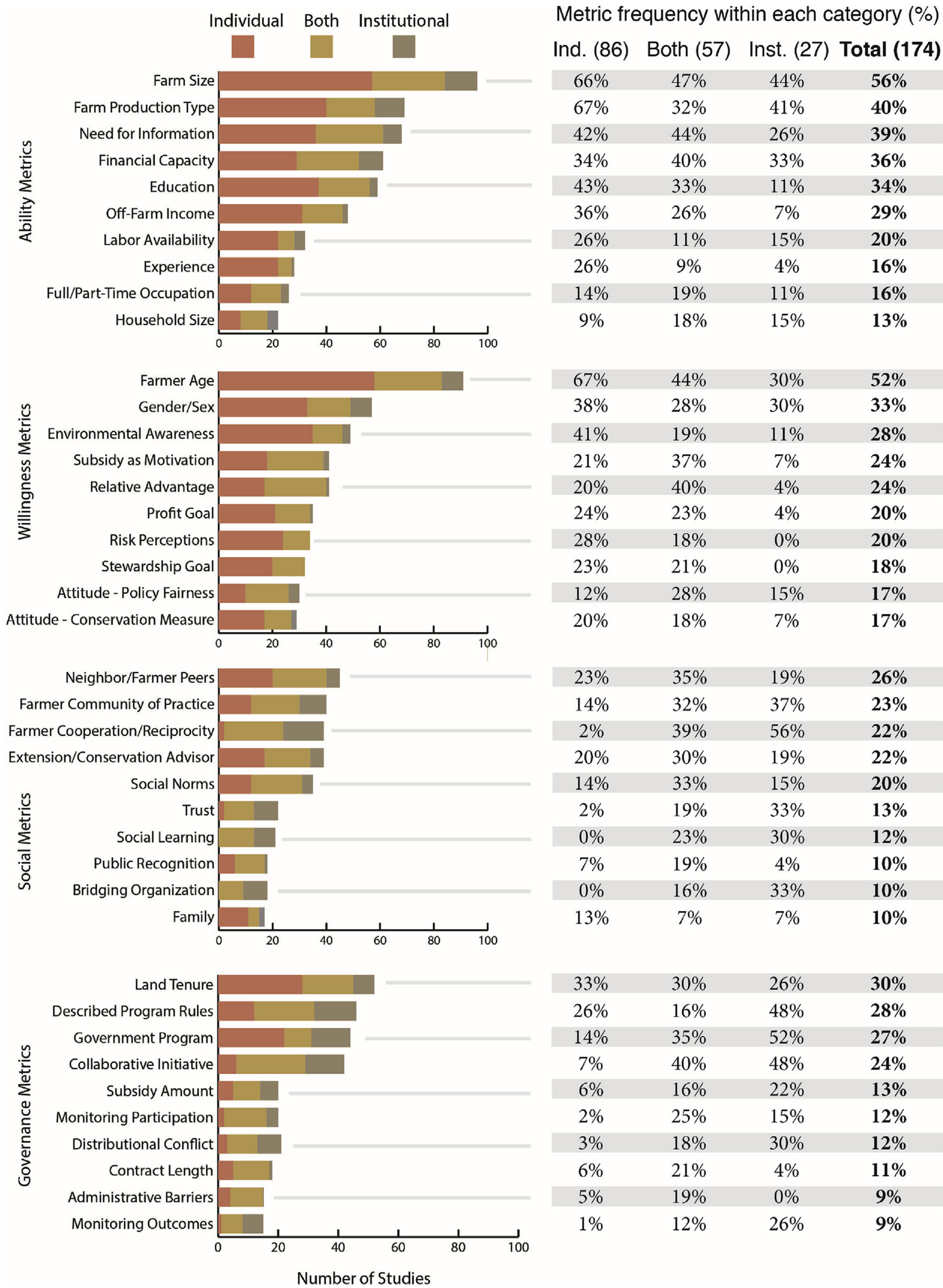
This paper set out to examine whether researchers measured the effectiveness of adoption practices, if studies focused solely on decision-making rationales within the farm or situated adoption decisions in broader institutional contexts, and how scholars have characterized the human-natural system in practice. Our findings illustrate that greater integration of biophysical and social systems, especially to analyze the conservation outcomes tied to adoption, is urgently needed. The most common metrics focused on farmer demographic information, while only 10% of studies measured whether adoption was effective for conservation. While our findings support the calls of other adoption reviews for greater integration of biophysical and institutional contexts into adoption analysis (Reimer et al., 2014; Burton and Paragahawewa, 2011), we offer three recommendations for advancing a coupled human-natural systems framework for conservation practice adoption research.

5.1. Research needs to measure conservation outcomes and track how those changes feed back into farmer perceptions and social norms toward CP adoption

First, integrating conservation outcomes tied to adoption would provide valuable information that could *feedback* into farmer perceptions and social norms about the utility of and need for adopting CPs. Having information on CP effectiveness tied to the biophysical dimensions of farms, farm production systems, and financial and social incentives or barriers to adoption of specific CPs would make it easier to discern which aspects of farmer ability and willingness are critical to adoption. Currently, most adoption metrics do not provide sufficient detail on location, extent, intensiveness, and continuity to measure or model farm-specific conservation outcomes. Prior research has demonstrated the important effect of this knowledge in shaping perceptions around farm-specific CP adoption and narratives affecting social norms (McGuire et al., 2013; Yoder and Roy Chowdhury, 2018). If measured in combination with farmers' perceptions of individual CPs as effective or ineffective for their farm, conservation outcome data could change expectations about the usefulness of adoption, while also addressing issues of reciprocity by demonstrating the aggregate effects of widespread adoption beyond the farm scale. Echoing Reimer et al. (2014), longitudinal, place-based research could permit researchers to develop more fine-grain analysis of the coupled system to help reveal these complex and farm- and farmer-specific contextual factors.

5.2. Research needs to consistently measure how agri-environmental programs mediate the social acceptance of CP adoption

Second, socio-cultural responses are critical to whether such conservation outcome data can be leveraged to lessen resistance to and



		Ind. (86)	Both (57)	Inst. (27)	**Total (174)**
Ability Metrics	Farm Size	66%	47%	44%	**56%**
	Farm Production Type	67%	32%	41%	**40%**
	Need for Information	42%	44%	26%	**39%**
	Financial Capacity	34%	40%	33%	**36%**
	Education	43%	33%	11%	**34%**
	Off-Farm Income	36%	26%	7%	**29%**
	Labor Availability	26%	11%	15%	**20%**
	Experience	26%	9%	4%	**16%**
	Full/Part-Time Occupation	14%	19%	11%	**16%**
	Household Size	9%	18%	15%	**13%**
Willingness Metrics	Farmer Age	67%	44%	30%	**52%**
	Gender/Sex	38%	28%	30%	**33%**
	Environmental Awareness	41%	19%	11%	**28%**
	Subsidy as Motivation	21%	37%	7%	**24%**
	Relative Advantage	20%	40%	4%	**24%**
	Profit Goal	24%	23%	4%	**20%**
	Risk Perceptions	28%	18%	0%	**20%**
	Stewardship Goal	23%	21%	0%	**18%**
	Attitude - Policy Fairness	12%	28%	15%	**17%**
	Attitude - Conservation Measure	20%	18%	7%	**17%**
Social Metrics	Neighbor/Farmer Peers	23%	35%	19%	**26%**
	Farmer Community of Practice	14%	32%	37%	**23%**
	Farmer Cooperation/Reciprocity	2%	39%	56%	**22%**
	Extension/Conservation Advisor	20%	30%	19%	**22%**
	Social Norms	14%	33%	15%	**20%**
	Trust	2%	19%	33%	**13%**
	Social Learning	0%	23%	30%	**12%**
	Public Recognition	7%	19%	4%	**10%**
	Bridging Organization	0%	16%	33%	**10%**
	Family	13%	7%	7%	**10%**
Governance Metrics	Land Tenure	33%	30%	26%	**30%**
	Described Program Rules	26%	16%	48%	**28%**
	Government Program	14%	35%	52%	**27%**
	Collaborative Initiative	7%	40%	48%	**24%**
	Subsidy Amount	6%	16%	22%	**13%**
	Monitoring Participation	2%	25%	15%	**12%**
	Distributional Conflict	3%	18%	30%	**12%**
	Contract Length	6%	21%	4%	**11%**
	Administrative Barriers	5%	19%	0%	**9%**
	Monitoring Outcomes	1%	12%	26%	**9%**

Fig. 5. Top 5 metrics in Framer Ability willingness Social Influences, and Governance Arrangements.

improve the legitimacy of CP adoption. Our findings demonstrate that the most prevalent institutional metrics are the presence or absence of different social connections and descriptions of agri-environmental program rules. While both types of metrics are important, they are insufficient to explain changing attitudes and social norms that are necessary to generate the widespread adoption required to address regional environmental challenges. Two factors that clearly feed into the effectiveness of agri-environmental governance are (1) the visibility of farming (i.e., how strongly farming is affected by public reputation and prevailing social norms; Burton, 2004); and (2) how agri-environmental programs and policies engage dynamics linking farmers and the public discourse. Some research has already begun to look at these aspects (e.g., Emery and Franks, 2012; Del Corso et al., 2017; Leventon et al., 2017). Our findings highlighted a number of metrics addressing the

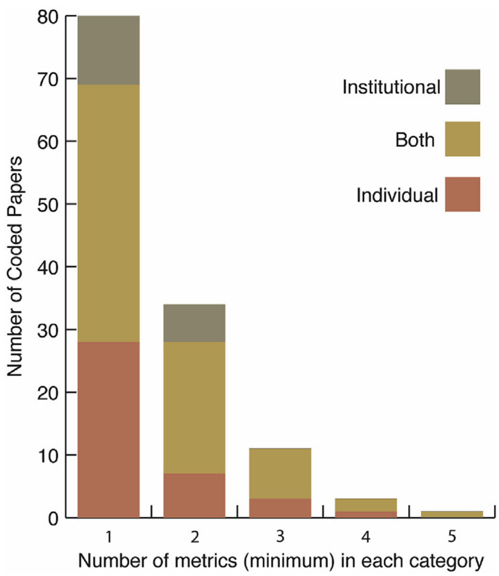


Fig. 6. While literature provides valuable diversity in the types of metrics characterizing the human-natural system, depth across different aspects of the system is lacking.

intersection of social acceptance and governance arrangements, such as *preference for flexibility/autonomy* (22 studies) and *public recognition* (18 studies). Future research must consistently gauge how CP adoption gains social acceptance within social networks and is amplified or diminished by agri-environmental programs to strengthen our understanding of farmers' adoption decision-making. Measuring conservation outcomes and tracking farmer adoption, non-adoption, and discontinued adoption over time will allow research to identify how social acceptance is intertwined with these different pathways.

5.3. Identifying institutional metrics that can be widely incorporated into study designs will advance synthesis efforts

Prior research on coupled human-natural systems has demonstrated the importance of and barriers to integrating data from social and natural science (Liu et al., 2007; Alberti et al., 2011; Stuart et al., 2015). Despite the challenges, a readily available step is for all researchers to build on the prevalence of farmer demographics, farm characteristics, and economic motivations to provide more consistent coverage, regardless of methodology. These data could then be paired with publicly available biophysical, spatial, and remotely sensing data. While this may only provide coarse integration at regional scales, it would provide an opportunity to advanced a coupled systems understanding. More challenging would be to identify institutional metrics that can be readily incorporating into study designs. One clear candidate is for the research community to provide a consistent definition and operationalization of social norms.

Currently, the social norm concept takes different forms, as opinion leaders within the diffusion of innovations frameworks (Rogers, 2003) or as personal, moral, or group norms within the theory of planned behavior (Mills et al., 2017). Operationalizing social norms consistently would require addressing the types of salient public and peer pressures that farmers experience, how those pressures complement or conflict with personal values and beliefs about conservation, and how new standards become accepted and enforced. Given the challenges of predicting why farmers adopt CPs, a coupled human-natural systems approach is necessary (Reimer et al., 2014). More consistent collection of metrics that attend to biophysical and institutional aspects would enable greater synthesis of the literature and advance our understanding of CP adoption and effectiveness.

Conflicts of interest

The authors report no conflicts of interest. Tabular data are available as a supplement to this publication. Landon Yoder led the study design, coding, data analysis, and writing with support from all co-authors.

Acknowledgements

This research was primarily supported by NSF award EAR 1505309, with additional support by the Environmental Resilience Institute, funded by Indiana University's Prepared for Environmental Change Grand Challenge initiative. The NSF award EAR 1331906 supported a portion of the time in this study for Dalrymple, Spak, Ward, and Yoder.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2019.02.009.

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